



Make-Up Exam

Answer All Question

Time : 1 Hour

Assume Any Missing Data

Question (1)

- Show how the blade of a Horizontal axis wind turbine is twisted from tip to root.
- Compare the efficiency of flat plate collector and parabolic trough collector showing which of them is higher.

Question (2)

An array of 10 solar flat-plate collector modules installed in parallel; each has an absorbing area of 8 m^2 , a heat removal factor of 0.8 & an overall loss coefficient of $8 \text{ W/m}^2\text{°C}$. They are connected to a water storage tank of 2 m^3 , which is initially at 40 °C . The storage tank loss coefficient-area product is 1.9 W and the tank is located outside. If the load flow is $1.667 \frac{\text{kg}}{\text{s}}$, and the make-up water is at 20 °C , calculate the performance of this system for the four-hour period shown in the following table

Hour	$S(\text{MJ/m}^2)$	$T_a(\text{°C})$
9-10	3.56	17.2
10-11	3.8	18.1
11-12	4.0	19.5
12-13	4.2	21

Question (3)

A cylindrical parabolic concentrator with width 5 m and length 50 m has an absorbed radiation per unit area of aperture of 600 W/m^2 . The receiver is a cylinder painted flat black and surrounded by an evacuated glass cylindrical envelope. The absorber has a diameter of 70 mm, and the transparent envelope has a diameter of 110 mm. The collector is designed to heat a fluid entering the absorber at 200°C at a flow rate of 0.18 kg/s . the fluid has $C_p = 3.26 \text{ KJ/Kg}^\circ\text{C}$. The heat transfer coefficient inside the tube is $300 \text{ W/m}^2^\circ\text{C}$ and the overall loss coefficient is $12 \text{ W/m}^2^\circ\text{C}$. The tube is made of stainless steel ($k = 16 \text{ W/m}^\circ\text{C}$) with a wall thickness of 5 mm. if the ambient temperature is 25°C , calculate the useful gain and exit fluid temperature.

Question (4)

For a site in Egypt with a most frequent wind speed of 9 m/s , you are requested to design a wind turbine used for pumping $22 \text{ m}^3/\text{hr}$ of water to a head of 22 m. For this purpose find:

- i) The rotational speed of the wind turbine
- ii) The wheel diameter
- iii) The axial thrust

Parabolic Concentrator

$$F' = \frac{\frac{1}{U_L}}{\frac{1}{U_L} + \frac{D_o}{h_{fi}D_i} + \left(\frac{D_o}{2k} \ln \frac{D_o}{D_i}\right)}$$

$$F'' = \frac{F_R}{F'} = \frac{\dot{m}C_p}{A_r U_L F'} \left[1 - e^{\left(-\frac{A_r U_L F'}{\dot{m}C_p}\right)} \right]$$

$$Q_u = F_R * A_a * \left[S - \frac{A_r}{A_a} U_L (T_i - T_a) \right]$$

Storage Tank

$$Q_u = F_R * A_c * [S - U_L (T_i - T_a)]$$

$$T_s^+ = T_s + \frac{\Delta t}{(mc_p)_s} [Q_u - L_s - (UA)_s (T_s - T_a)']$$

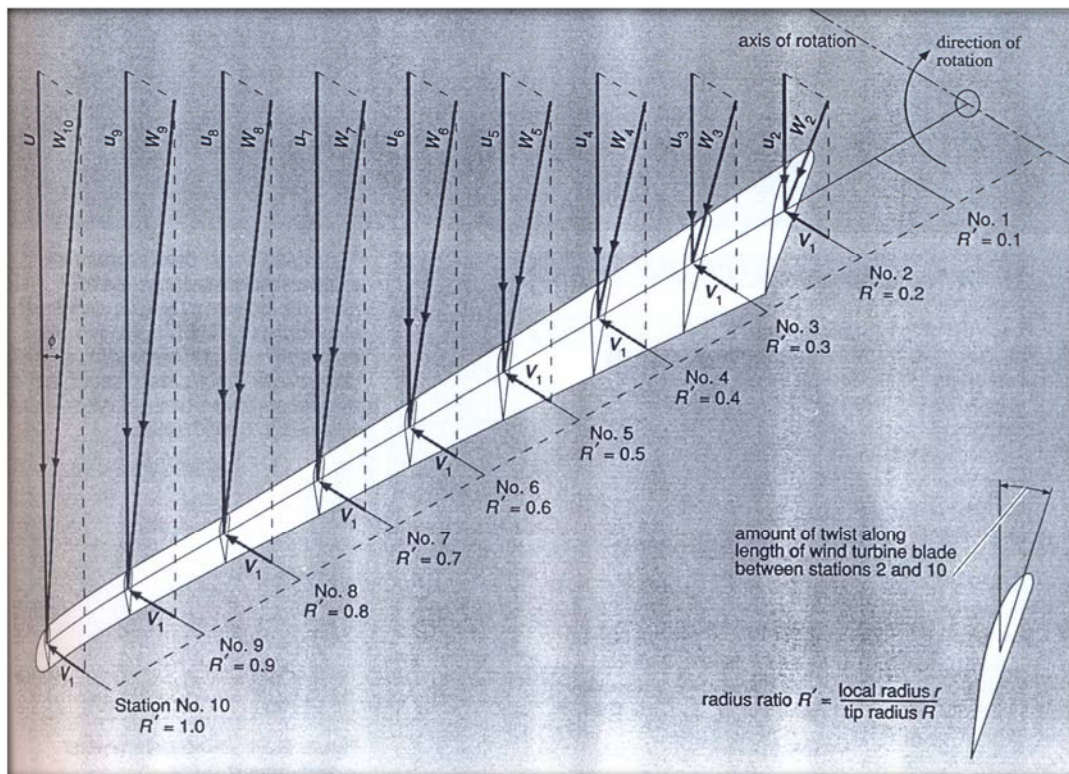
Wind Turbine

$$P = \frac{1}{2} C_p \rho A V_t (V_i^2 - V_e^2) ; C_p = 4a(1 - a^2); F_X = \rho A V_t (V_i - V_e)$$

Make-Up Exam Solution

Question (1)

a) The magnitude and direction of the relative wind angle ϕ , varies along the length of the blade according to the local radius, r . This is because the local tangential speed, u , of a given blade element is a function of the rotor's angular velocity Ω times the local radius, r , of the blade element. As the tangential speed decreases towards the hub, the relative wind angle ϕ progressively increases. If a blade is designed to have a constant angle of attack along its length, it will have to have a built-in twist, the amount of which varies progressively from tip to root, the figure below demonstrates the progressive twist of HAWT rotor blade.



b) The student has to show that the efficiency for the flat plate collector is related to the total radiation (direct + diffuse) while it is related to the direct radiation only in the case of parabolic trough collector. For flat plate collector optical losses are considerably small, temperature of heat loss area is very low and area of heat transfer is materially greater. In the case of parabolic trough collector, optical losses are much greater, temperature of surface losing heat is considerably greater, but area of heat transfer is much smaller. Accordingly, it seems that flat plate collector is more efficient.

Question (2)

For the period 9 – 10

$$Q_u = F_R * A_c * [S - U_L(T_i - T_a)]$$

$$A_c = 8 * 10 = 80 \, m^2$$

$$Q_u * \Delta T = 0.8 * 80 * (3.56 * 10^6 - 8 * 3600 * (40 - 17.2)) = 1.85 * 10^8 \, J$$

$$T_s^+ = T_s + \frac{\Delta t}{(mc_p)_s} [Q_u - L_s - (UA)_s(T_s - T_a')]_s$$

$$T_s^+ = 40 + \frac{1}{(2000 * 4200)_s} [1.85 * 10^8 - 140028 - (8)_s(40 - 17.2)] = 62.02^\circ C$$

Hour	$S(\frac{Mj}{m^2})$	$T_a(^{\circ}C)$	$T_s(^{\circ}C)$	$T_s^+(^{\circ}C)$
9 – 10	3.56	17.2	40	62.025997
10 -11	3.8	18.1	62.026	81.154127
11 -12	4	19.5	81.15413	97.839283
12- 13	4.2	21	97.83928	112.65022

Question (3)

Given

$$\begin{array}{llll} w = 5m & L = 50\text{ m} & s = 600 \frac{W}{m^2} & d_{r,o} = 70\text{ mm} \\ d_c = 110\text{ mm} & T_i = 200\text{ }^\circ\text{C} & \dot{m} = 0.18\text{ kg/s} & C_p = 3.26 \frac{Kj}{Kg^\circ\text{C}} \\ h_{f,i} = 300 \frac{W}{m^2K} & U_L = 12 \frac{W}{m^2}^\circ\text{C} & k = 16 \frac{W}{m^\circ\text{C}} & T_a = 25\text{ }^\circ\text{C} \end{array}$$

Required

$$Q_u, T_{f,o}$$

Solution

$$A_a = [\text{width} - d_c]L = [5 - 110^{-3}] * 50 = 244.5\text{ m}^2$$

$$A_r = \pi d_{r,o}L = \pi * 70 * 10^{-3} * 50 = 10.99\text{ m}^2$$

$$Q_u = F_R * A_a * [S - \frac{A_r}{A_a} U_L (T_i - T_a)]$$

$$F' = \frac{1}{\frac{1}{U_L} + \frac{D_o}{h_{fi} D_i} + \left(\frac{D_o}{2k} \ln \frac{D_o}{D_i} \right)}$$

$$= \frac{1}{\frac{1}{12} + \frac{70}{300 * 60} + \left(\frac{70 * 10^{-3}}{2 * 16} \ln \frac{70}{60} \right)} = 0.95173$$

$$F'' = \frac{F_R}{F'} = \frac{\dot{m} C_p}{A_r U_L F'} \left[1 - e^{\left(-\frac{A_r U_L F'}{\dot{m} C_p} \right)} \right]$$
$$= \frac{0.18 * 3260}{10.99 * 12 * 0.95173} \left[1 - e^{\left(-\frac{10.99 * 12 * 0.95173}{0.18 * 3260} \right)} \right] = 0.85673$$

$$F_R = F' * F'' = 0.95173 * 0.85673 = 0.90023$$

$$Q_u = F_R * A_a * [S - \frac{A_r}{A_a} U_L (T_i - T_a)]$$

$$= 0.90023 * 244.5 * \left[S - \frac{10.99}{244.5} * 12 (200 - 25) \right] = 105.9\text{ KW}$$

$$Q_u = \dot{m} C_p * (T_{f,o} - T_{f,i})$$

$$105.9 = 0.18 * 3.26 * (T_{f,o} - 200)$$

$$T_{f,o} = 340.09\text{ }^\circ\text{C}$$

Question (4)

$$\text{Power} = \frac{\gamma Q h}{\eta_p} = \frac{1000 * 9.81 * 22 * 22}{3600 * 0.75} = 1758.54 \text{ KW}$$

$$P = \frac{1}{2} C_p \rho A V_t (V_i^2 - V_e^2)$$

$$1758.54 = \frac{1}{2} 0.45 * 1.23 * \frac{\pi}{4} * D^2 * 9^3$$

$$D = 3.33 \text{ m}$$

$$\lambda = \lambda_{\text{opt.}}$$

$$\frac{2\pi N R}{60 V_t} = \frac{4\pi}{n}$$

$$\frac{2\pi N * 1.665}{60 * 9} = \frac{4\pi}{8}$$

$$N = 81.08 \text{ rps}$$

$$F_X = \rho A V_t (V_i - V_e)$$

$$= 1.23 * \frac{\pi}{4} * 3.33^2 * 9^2 = 875.65 \text{ N}$$